Idaho National Laboratory Research & Development

Impacts

INL Idaho National Laboratory

FROM THE Director

John Grossenbacher
Director, Idaho National Laboratory

January 2013

The U.S. Department of Energy's national laboratories play a crucial role by conducting the type of research, innovation, testing and evaluation that is beyond the scope of regulators, academia or private industry alone.

Idaho National Laboratory's engineering expertise and applied science capabilities are particularly focused on deployment of technologies for nuclear energy, national security and new energy resources. A broad array of infrastructure, nuclear material inventory and vast expertise converge at INL, the nation's nuclear energy laboratory.

In these and other areas, INL uses these capabilities to innovate, evaluate and deploy new technologies that help protect the nation's resources and advance energy security. Productive partnerships with academia, industry and government agencies also help deliver high-impact outcomes.

This edition of INL's Impacts magazine highlights our newest leadership efforts, capabilities, collaborations and research accomplishments. Please take a few minutes to learn more about the critical resources and transformative innovations at one of the nation's premier applied-science laboratories.

On the cover
The Sophia software tool helps defend industrial control system networks against cyberattack by making it easier for operators to find and investigate anomalies that may threaten security. More on page 10.

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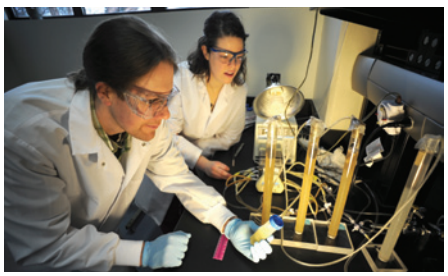


INL: BUILDING A BRIGHT Future

The U.S. today faces a number of national challenges related to energy security, infrastructure security and cybersecurity. The Department of Energy (DOE) multiprogram national labs are especially suited to find solutions that may be too risky or complex for industry, academia or regulators to tackle alone.

Idaho National Laboratory (INL) is distinct within the U.S. national laboratory complex for its strong focus on engineering and applied science. Exceptional expertise, strategic partnerships, and a growing one-of-a-kind testing infrastructure converge here to create an incubator that helps new ideas mature toward the marketplace.

Since the lab's founding as the National Reactor Testing Station, it's always focused on testing and demonstration that helps reduce risks associated with deploying new concepts for large-scale, real-world use. Today, INL hosts test beds for technology ranging from wireless communications to biofuels feedstock processing. Most of the national research capabilities that are unique to nuclear energy reside at INL, the nation's nuclear energy laboratory. Consider INL's skilled personnel and extensive partnerships, and a picture emerges of a national resource capable of addressing myriad current and future national challenges.

For example, INL developed an advanced modeling and simulation platform that has fundamentally changed how scientists approach such work. The technology is now used by 25 national labs, universities and private companies to investigate tough questions in nuclear energy, materials science, geology and other disciplines. This year, the lead developer became the first INL researcher to earn a Presidential Early Career Award for Scientists and Engineers.

Such work illustrates the thought leadership INL provides to the nation and the DOE. By recruiting the best experts in their fields and capitalizing on our systems engineering expertise, INL offers big-picture insights. Examples in the pages that follow illustrate INL's leadership related to nuclear energy as well as national security and advanced energy systems.

Productive collaborations also underlie success, and numerous successful partnerships from the past year are highlighted. Similarly, INL is building on its geography and physical infrastructure through ongoing enhancement of state-of-the-art testing and evaluation capabilities. Adding to INL's momentum is a new leadership team overseeing the lab's science and technology research, a small sampling of which is described in the Advancing Technology section. Finally, achievements from the Center for Advanced Energy Studies — an unprecedented partnership between INL and Idaho's public research universities — illustrate how INL is helping redefine the relationship between federal and state institutions.

Overall, this snapshot of recent achievements illustrates how INL research innovation, testing and evaluation is helping apply new energy solutions to safely, securely and sustainably advance nuclear energy, safeguard infrastructure, expand energy supply and improve efficiency.

Akira Tokuhiro, University of Idaho professor of mechanical and nuclear engineering, talks with graduate student Mark Albiston at the Center for Advanced Energy Studies at INL.

NUCLEAR Leadership

The Nation's Nuclear Energy Lab

INL has led a fundamental shift in the DOE approach to nuclear research and development at the Department of Energy's national labs, universities, and within regulatory and policy organizations. The lab is leading an approach that combines physical theory, advanced modeling and simulation, and small-scale experiments that test fundamental concepts. When engineering-scale irradiation testing or large-scale demonstrations are necessary, this approach improves efficiency and reduces uncertainty.

Technical leadership
In 2009, INL worked closely with the DOE's Office of Nuclear Energy (DOE-NE) and led a team of national laboratories to develop the *Nuclear Energy Research and Development Roadmap*. The roadmap serves as a foundation of the Nuclear Energy Research Development and Demonstration (RD&D) program and a balanced plan of research aimed at addressing key challenges to nuclear energy viability. INL input and expertise continue to help DOE-NE develop a research strategy consistent with this roadmap.

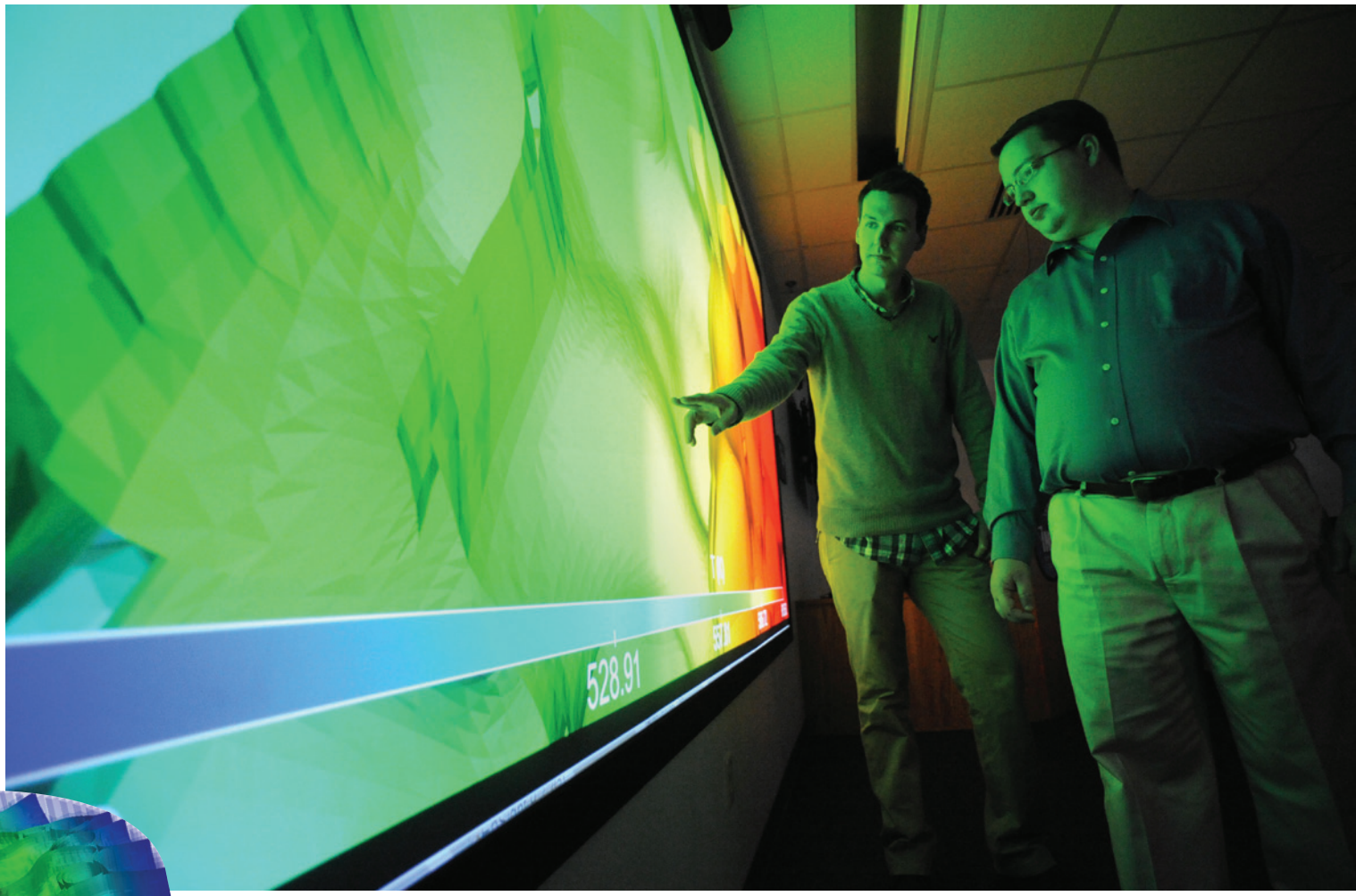
From INL's onset, the Technical Integration Office (TIO) concept has helped integrate DOE-NE research across national laboratories, universities and industry, enabling key linkages to the international research community. Using resident capabilities under three technical integration offices, INL emerged as a leader in areas of fuel development, separations research and waste form development, systems analysis, risk and safety analysis, and demonstration of reactor and fuel cycle technologies. In FY 2012, DOE expanded the INL technical integration role to include radioisotope power systems and the emerging area of used fuel RD&D. This initiative will become increasingly important as industry and regulators examine the technical basis for long-term storage of used fuel and waste confidence.

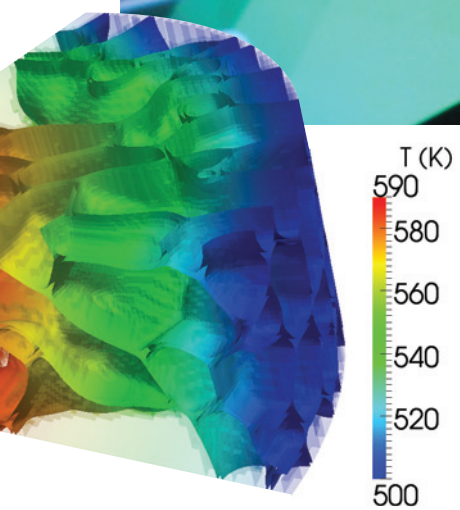
Advanced modeling and simulation
In the year since this magazine first described the MOOSE simulation platform (Multi-physics Object Oriented Simulation Environment), it has gained broad national recognition and a large user base among forefront efforts to develop a massively parallel computational framework. MOOSE has allowed nuclear fuels and materials scientists to develop numerous MOOSE-based applications that predict the behavior of fuels and materials under operating and accident conditions. BISON, MARMOT, PEREGRINE, RAVEN, Grizzly, RattleSnake, Fox, and Pronghorn all are members of the MOOSE "herd" (more modeling and simulation on pp. 19, 24).

"Many folks here in Idaho played a key role in helping us shape the objectives on that Nuclear Energy Roadmap."

—Peter Lyons, DOE's assistant secretary for Nuclear Energy

The MARMOT application developed by Michael Tonks, right, models microstructural changes that nuclear fuel undergoes during fission. MARMOT runs on the MOOSE simulation platform developed by Derek Gaston, left, and others.

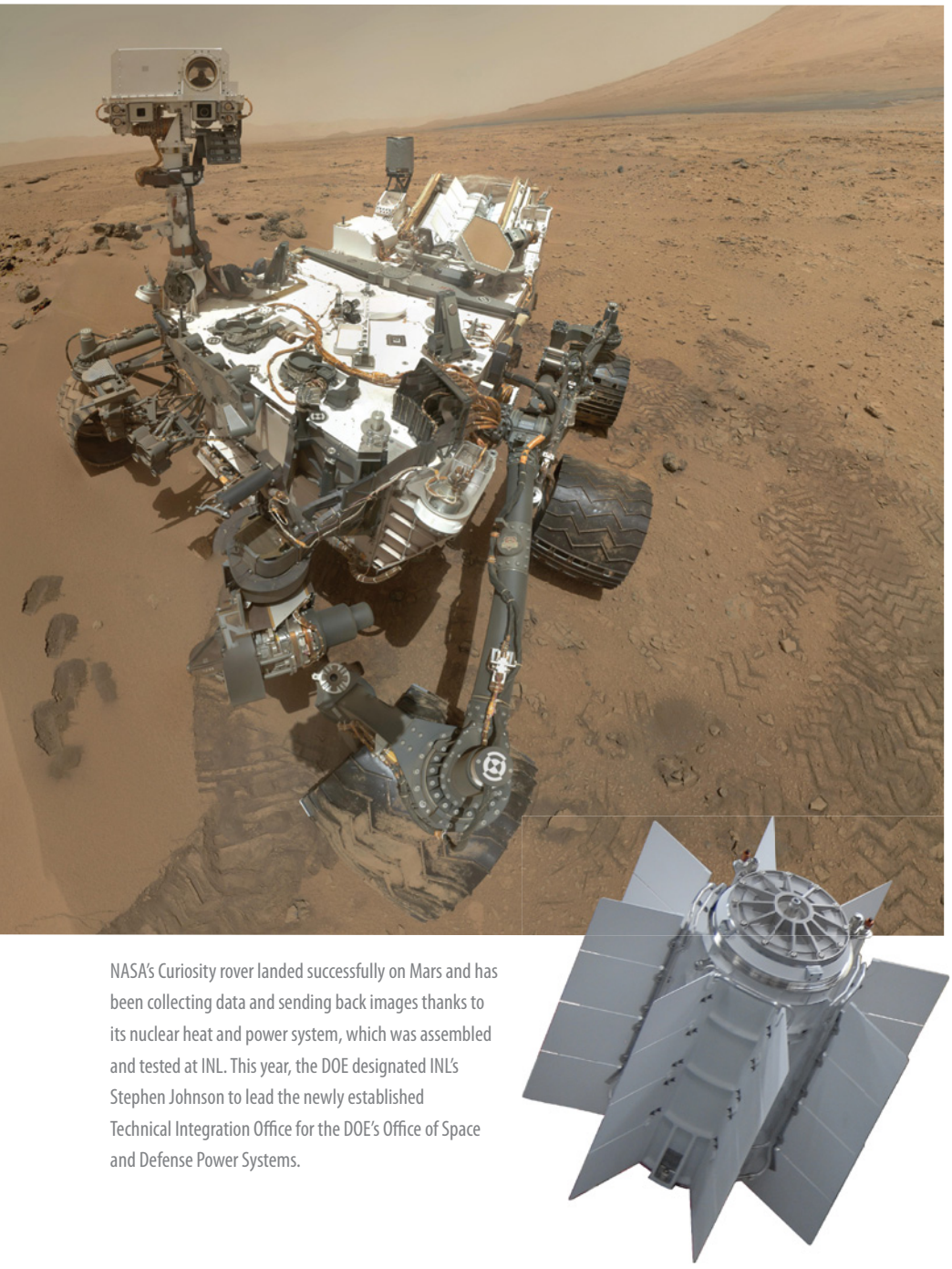




These applications support the commercial industry and multiple research programs for DOE-NE including: the Consortium for Advanced Simulation of LWRs, the Fuel Cycle R&D campaign, the Light Water Reactor Sustainability program, the Reduced Enrichment for Research and Test Reactors program, and efforts to develop fuels with enhanced accident tolerance. In short, MOOSE and its herd of applications have provided a significant early success for DOE-NE's Advanced Modeling and Simulation program.

Other MOOSE applications help tackle non-nuclear questions such as those associated with carbon dioxide sequestration or environmental remediation of chemical spills (RAT), high-temperature superconductivity (Condor), and engineered geothermal systems (FALCON, more on pg. 36).

NUCLEAR Leadership (CONT.)



NASA's Curiosity rover landed successfully on Mars and has been collecting data and sending back images thanks to its nuclear heat and power system, which was assembled and tested at INL. This year, the DOE designated INL's Stephen Johnson to lead the newly established Technical Integration Office for the DOE's Office of Space and Defense Power Systems.

Light Water Reactor Sustainability
A number of the MOOSE applications support the DOE's Light Water Reactor Sustainability (LWRS) program. For example, INL is leading work to enable a more accurate representation of a nuclear power plant's safety margin. The program's Risk-Informed Safety Margin Characterization Pathway is developing a toolkit that includes the MOOSE-based applications RAVEN, Peacock and Grizzly. The Grizzly application, for example, aims to provide precise information about the aging of components such as reactor pressure vessels and the impact of that aging on safety margins.

INL leads the LWRS program's Technical Integration Office (TIO) and three of the four technical pathways. Planning, execution and implementation of the LWRS program are coordinated with the nuclear industry—with the Electric Power Research Institute as a major partner—the Nuclear Regulatory Commission, universities and related DOE R&D programs. In January 2012, the TIO issued an Integrated Program Plan describing the program's objectives, technical plans, and interfaces with industry partners and other DOE programs.

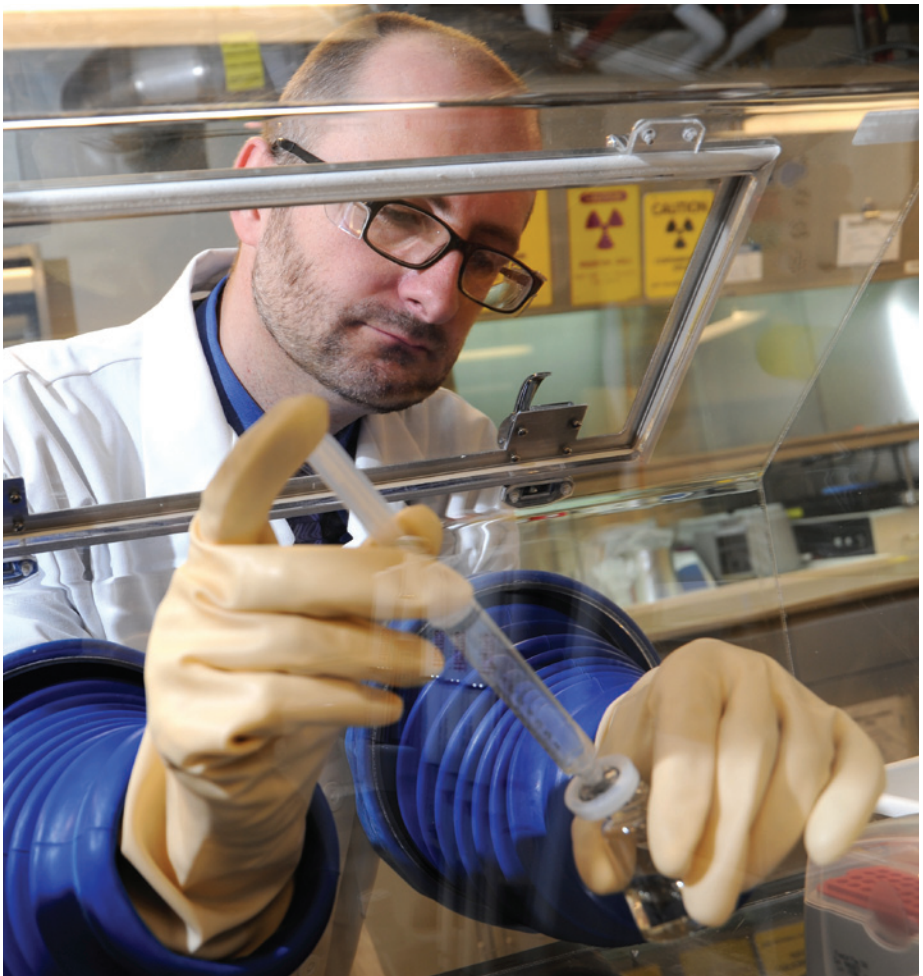
Nuclear separations
Part of the DOE's Fuel Cycle Technology research program focuses on the processing of used nuclear fuel into useable material and stable waste forms. This year, the DOE-NE Separations and Waste Forms campaign underwent an extensive relevancy review by a preeminent panel of independent experts.

The panel concluded that the campaign had an outstanding program in place with relevant R&D activities yielding more than 500 publications illustrating results-oriented work of campaign members contributing from across the DOE complex.

The review, commissioned by DOE's deputy assistant secretary for Fuel Cycle Technology, also included an assessment of progress toward establishing a science-based approach to nuclear separations research. The concept is novel, and after expressing initial skepticism as to whether this was possible, the panel concluded that the science-based approach was achieving success. Finally, the creation of "sigma teams" is enhancing collaborations between national labs on separation and waste form grand challenges. These teams began showing momentum and promise this year.

"We are impressed by the caliber and breadth of technical managers and researchers that are involved. You have engaged the top people in the country in all areas of work.... In short, the program is in good hands."

—Relevancy Review Panel, Separations and Waste Form Campaign

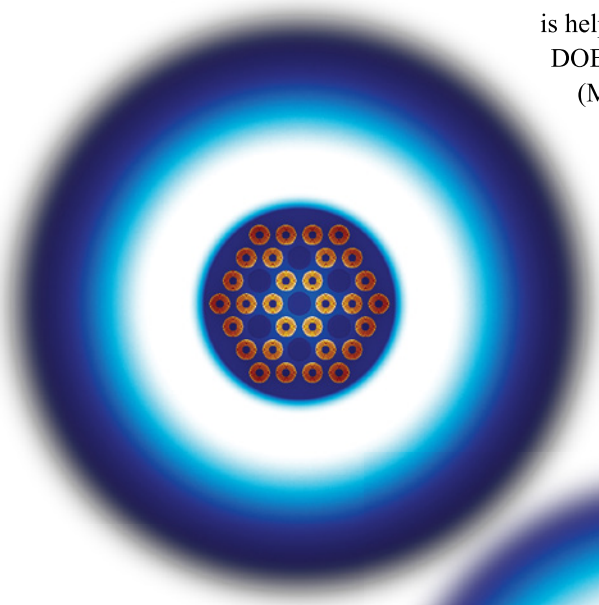


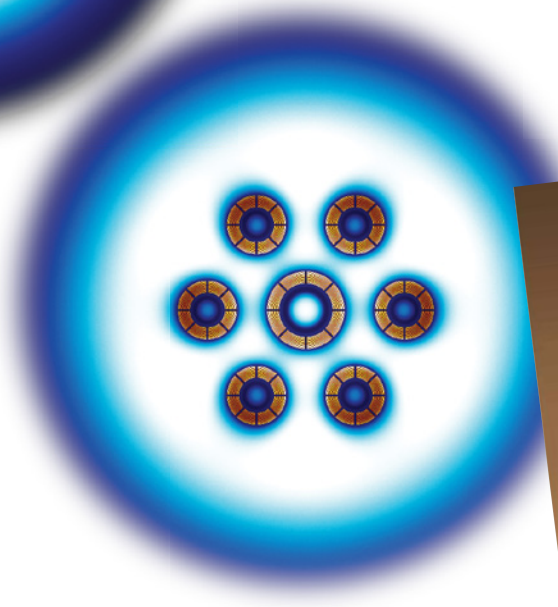
Used fuel handling

Establishing a strong technical basis for safe and secure storage and transportation of used nuclear fuel is essential for the sustainability of nuclear power generation. This year, INL helped DOE-NE develop a new RD&D plan for Used Fuel Storage and Transportation. The plan outlines science-based activities, identifies facilities and resources needed to close technical or knowledge gaps, and summarizes activities necessary to assure high confidence in safe and secure long-term storage and transportation. INL also worked with the Used Fuel Disposition Campaign this year to establish a new element for field demonstrations.

Peter Zalupski, who received INL's Early Career Exceptional Achievement Award in FY 2012, researches advanced methods for recycling valuable components from used nuclear fuel.

NUCLEAR Leadership (CONT.)





Next-generation test reactor

The costs associated with maintaining DOE test reactors and converting them to use low-enriched uranium may make it practical to consider building a single new research reactor. INL work to design a next-generation test reactor is helping lead such a discussion at the DOE. Designs, below, for MATRIX (Multiple Application Test Reactor for Irradiation Experiments) aim to accommodate the diverse research needs of the DOE's many current customers. To create a reactor that could also use low-enriched uranium, the design team is working in tandem with the INL experts designing such fuels.

Nuclear Hybrid Energy Systems

The potential for sustainable use of nuclear, fossil and renewable resources could be expanded through hybrid energy systems. Linking nuclear, fossil and renewable energy systems could make more efficient use of excess heat and electricity that go to waste when systems are operated in isolation. This year, INL led the creation of a Nuclear Hybrid Energy Systems Capability Development Plan, which was issued to the DOE in August 2012. The plan describes development of computational tools, intelligent monitoring and controls, and user interfaces necessary to advance deployment of these systems. It also outlines a five-year approach toward demonstration that would involve collaborations with sister national labs (more hybrid energy on pp. 12, 35).

Enhancing accident tolerance
December 2011 congressional appropriation language directed DOE-NE to develop nuclear fuels and cladding with enhanced accident tolerance. This enabled DOE-NE to expand the fuel cladding development it was already doing under the LWRS program. Such fuels would be able to tolerate loss of active cooling in the reactor core for a considerably longer time while maintaining or improving performance during normal operations and abnormal events. INL helped draft a DOE roadmap for the research effort and has strategic leadership of DOE's Fuel Cycle R&D Advanced Fuels Campaign, which is setting the RD&D direction for fuels with enhanced accident tolerance. INL worked with the campaign to organize a two-day October workshop to begin establishing success metrics to quantify desired attributes and associated constraints, for fuels with enhanced accident tolerance.

"Idaho National Lab has been instrumental and important in the health of nuclear energy in our country and worldwide. Going forward, that importance doesn't decrease, in fact, it increases."

—Marvin Fertel, Nuclear Energy Institute president and CEO, in testimony to Idaho's LINE Commission

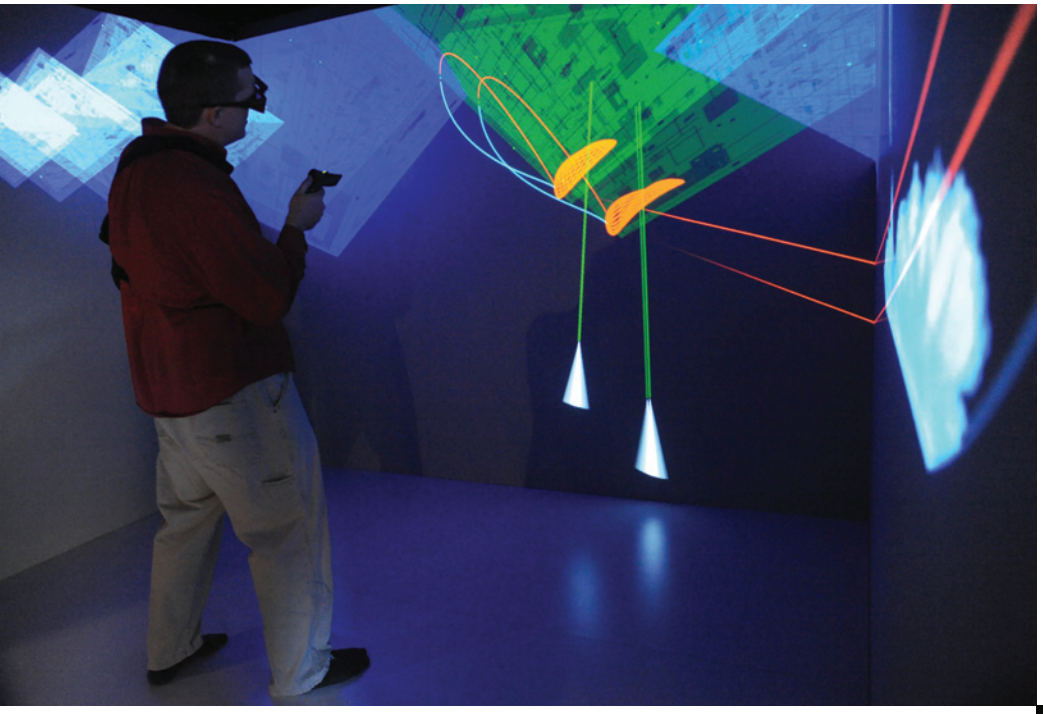
Next-generation test reactor designs, far left, need to accommodate many DOE customers. Members of the Idaho governor's Leadership in Nuclear Energy (LINE) Commission, above, toured INL nuclear research facilities.

LINE Commission
INL helped lead the creation and execution of Idaho's Leadership in Nuclear Energy (LINE) Commission. The commission is charged with making recommendations to the governor on state policies and actions to support and enhance the long-term viability and mission relevance of INL and the state's broader nuclear industry. INL Lab Director John Grossenbacher chairs the technology subcommittee, and senior INL leaders sit on three of the other four subcommittees. The commission delivers its final report to the governor in 2013.

ENERGY AND NATIONAL Security

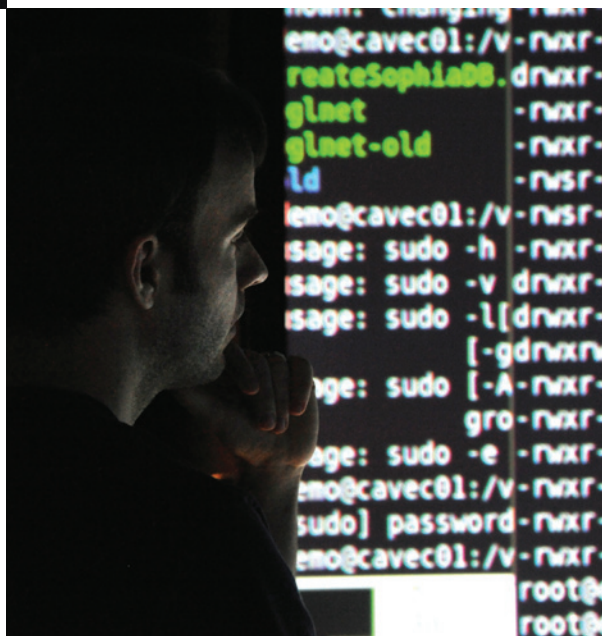
Multiprogram capabilities

INL is a multiprogram national lab that supports national security and new energy solutions. INL's isolated site, test bed infrastructure and applied science focus are ideal for experimentation, assessments and demonstrations that help deploy new technology to protect the nation's resources and critical infrastructure.



Securing control systems
INL developed the Sophia software to help network operators detect anomalies that may threaten control systems running the nation's utilities and other infrastructure. The software passively monitors network communication pathways and patterns so it can alert operators to unusual activity. The lab's extensive expertise evaluating cyber vulnerabilities for industry gave developers insight into the need for such a tool, which is the first of a suite in development at INL. Dozens of energy sector companies helped beta test the Sophia software, and INL is now working to transition it to industry (more cybersecurity on pp. 18, 30).

The Sophia cybersecurity software can be loaded, right, into the Computer Assisted Virtual Environment (CAVE) at INL, where co-developer Gordon Rueff, above, demonstrates its features.



Protecting the grid
Solar storms, which are predicted to become more frequent in 2013, can induce geomagnetic currents that can damage the electric power grid. The Defense Threat Reduction Agency hired INL to test a commercially available mitigation strategy that can thwart transformer damage from such storms. That test — the first such full-scale test on a live transmission grid — evaluated mitigations under different load and current conditions.

Collecting this type of full-scale, objective test data validates models and advances the nation's understanding of how to protect the grid from these significant phenomena. INL can perform such unbiased analysis using its distinctive grid-testing capability. The lab operates a 61-mile, 138-kV dual-fed power loop complete with several substations. Portions of the utility-scale power loop can be isolated for independent, full-scale, real-time testing. This capability enables a wide array of testing that can help industry and regulators work toward a more secure and resilient electrical grid.

Wireless spectrum sharing
INL innovation in wireless communications received national and international recognition via three awards for a technology described in this publication last year. The Wireless Spectrum Communications (WSComm) technology identifies and utilizes available spaces in the radio frequency spectrum. A unique method for spreading the transmission signal enables its receiver to avoid frequency spectra that are plagued with interference. The technology addresses continued commercial expansion while simultaneously serving the needs of national security, public safety and other crucial next-generation communication systems. Developed in part in collaboration with University of Utah researchers, it won an R&D 100 Award, a Far West Federal Laboratory Consortium award, and an Idaho Innovation Award.

Safeguarding nuclear material
Building upon core expertise in nuclear fuel and civilian nuclear energy technologies, INL has grown into a leading world resource for securing and safeguarding nuclear material. The lab's experts collaborate with other national laboratories, industry and academia to develop enhanced proliferation-resistant reactor and fuel cycle designs and safeguards instrumentation. INL also provides unique facilities, materials and technical expertise to support global nuclear security activities, the national technical nuclear forensics community, and the training of nuclear emergency first-response personnel at the local, state, tribal and national levels.

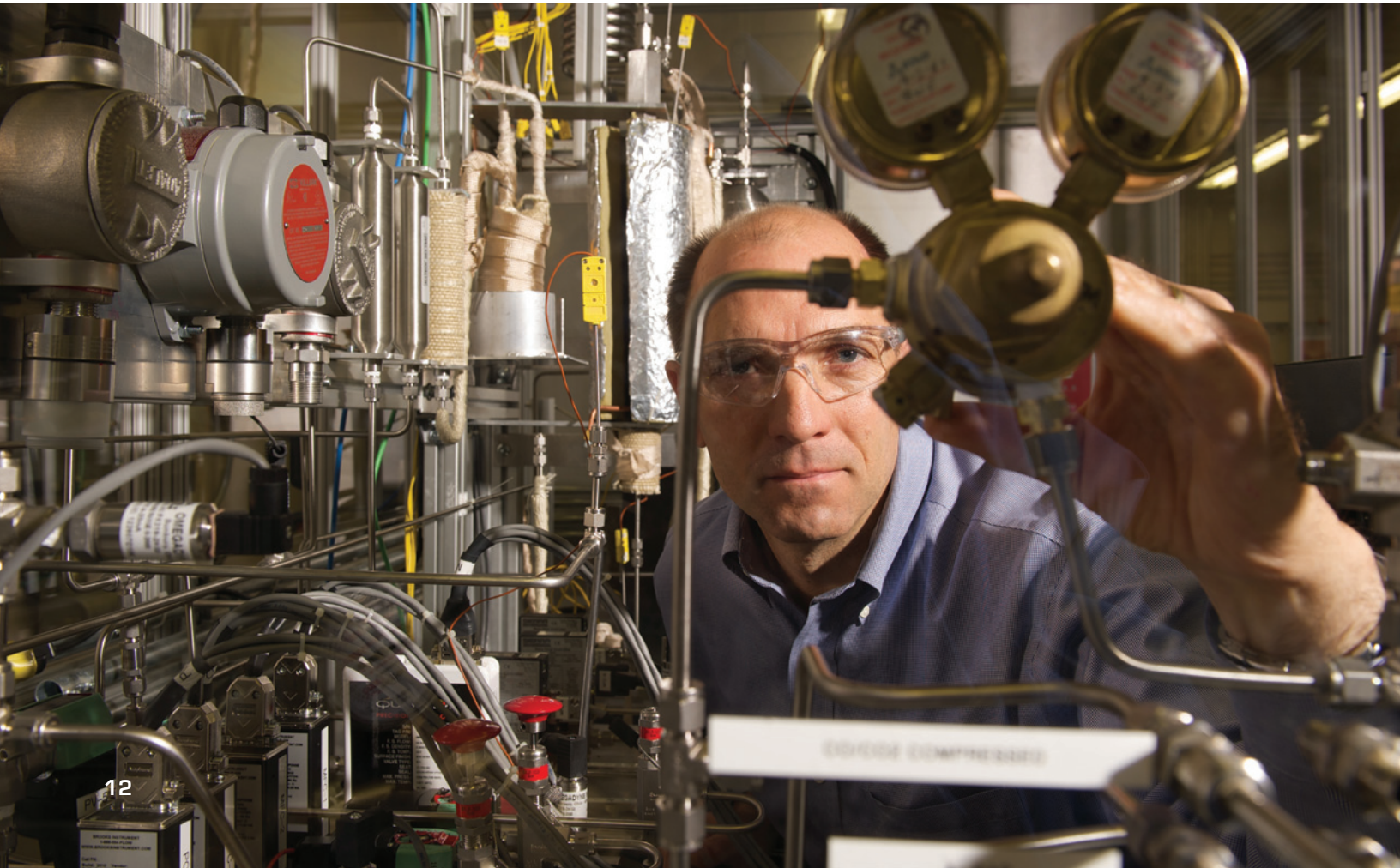
As a result, INL is becoming recognized as a center for nonproliferation and global security technology research, development, demonstration and deployment. New collaborative projects, development and deployment of safeguards technologies, and unique detection technologies have led to this recognition. These efforts are helping achieve national and DOE objectives for enabling international safeguards.

ENERGY AND NATIONAL Security

Advancing energy systems

Hybrid systems that pair two or more energy sources could yield numerous energy security benefits. INL has strategically led hybrid energy system concepts with the development and application of high-performance dynamic modeling and other computational tools, as well as system development and demonstration using hardware-in-the-loop. INL also has built collaborations and described a validation plan. Such work boosts the lab's recognition as a key provider of science and technology to help solve energy security challenges.

INL has established collaborative agreements with the DOE's National Renewable Energy Laboratory, the Chinese Academy of Sciences, the state of Wyoming, General Electric, and two nuclear reactor technology development companies. These partnerships enable INL to leverage the testing capabilities of NREL, Wyoming's School of Energy Resources and private industry to validate components of hybrid energy systems. INL's testing capabilities will help better understand, develop, demonstrate and deploy hybrid energy systems in the U.S. (more hybrid systems on pp. 8, 35).



Advance Process and Decisions Manager Richard Boardman leads collaborations to help demonstration hybrid energy systems.

Enhancing energy storage
Performance testing of energy storage devices is critical to the large-scale deployment of renewable energy and advanced vehicles. INL is regarded as a leading national laboratory in energy storage testing and analysis. It has a proven record of accomplishment in evaluating advanced energy storage devices and developing test and analysis procedures. In addition, the U.S. Department of Transportation and the DOE enlisted INL to work with the National Fire Protection Association to update emergency response procedures for electric vehicle battery incidents.

The DOE recognized the lab's expertise in advanced vehicle and energy storage technology by including INL in the invitation-only DOE Electric Vehicle (EV) Everywhere Planning Meeting with Energy Secretary Steven Chu. The EV Everywhere Challenge is a DOE "Clean Energy Grand Challenge" that strives to enable U.S. companies to be the first in the world to produce affordable and convenient plug-in electric vehicles within the next 10 years (more advanced vehicles and energy storage on pg. 34).

Optimizing biofuels production
INL has been involved in several efforts that are helping private companies convert coal-fired power plants to run instead on biomass. For example, INL is working with the Electric Power Research Institute (EPRI) to analyze and demonstrate the feasibility of supplementing and substituting biomass for coal in electrical utility boilers. The team will analyze sustainable biopower co-firing, biomass processing, assembly and supply, and combustion tests. INL is also working with EPRI to develop biomass feeder material for potential co-firing tests in Alabama and Oregon.

INL is testing and analyzing biomass feeder materials that could be used to convert the Boardman, Ore., coal-fired plant to a biomass-fired plant. The lab is working with Pacific Gas and Electric Company and EPRI to convert energy crops being developed by PG&E into feedstocks that could be burned in the Boardman plant. The team is preparing for a trial-burn of biomass in FY 2014. This project enables a major Northwest utility to develop clean energy options that help meet state of Oregon renewable energy portfolio standards (more biofuels on pg. 35).

Collaborations WITH...

The nuclear energy industry

Collaborations with the nuclear energy industry help INL advance nuclear energy production and safety. Utilities, reactor vendors, fuel providers and companies ranging from startups to industry leaders can access INL analysis and expertise. Numerous agreements enable INL to share knowledge and capabilities that are most relevant to industry.

Updating control rooms
A series of pilot projects at commercial nuclear power generating stations and in INL's Human Systems Simulation Lab aimed to help upgrade reactor control rooms. The projects demonstrated digital technologies that can help modernize reactor information, instrumentation and control systems. One proposed upgrade under development has the potential to be implemented in nine U.S. nuclear power plants. INL has engaged in such work with a variety of companies including Exelon Generation Company, LLC, Southern California Edison Company, and Duke Energy.

INL's new Human Systems Simulation Lab includes 15 panels that are easily reconfigured to replicate the nation's commercial plant control rooms for training and modernization.

The Department of Energy has a long tradition of making national lab capabilities available to businesses developing new technologies. INL helps advance the nuclear industry by sharing its analyses and expertise with utilities, reactor vendors, fuel providers, and companies ranging from startups to industry leaders. Here are some of the companies that established collaborations with INL in FY 2012.

Enhancing accident tolerance
INL provides technical expertise and laboratory facilities to design advanced nuclear reactors and fuels that can tolerate damage under extreme circumstances such as loss of coolant accident scenarios. Specifically, such systems would operate as well as current options, but be able to tolerate loss of active cooling for longer periods of time. For example, INL is part of a research team that is developing a high-power reactor concept with inherent safety features. The team, which includes Westinghouse Electric Company and Southern Nuclear Operating Company, is receiving DOE research funding. INL also is part of a university research team that received DOE funding to fabricate and evaluate new cladding for fuel with enhanced accident tolerance.

Informing reactor design
A long history designing and building reactors at INL has provided a wealth of knowledge. Established companies such as Babcock & Wilcox Nuclear Energy Inc. (B&W), and startup companies such as NuScale Power, Inc. seek to learn from the lab's experience. INL has pending and established agreements with many companies to provide technical expertise. Such information can help companies develop both small and large advanced reactor designs.

Analyzing reactor safety
INL has developed the industry's premier modeling tools for reactor and fuel development and has licensed these tools for use around the world. The most famous is the Reactor Excursion and Leak Analysis Program (RELAP). The latest licensed version, RELAP5-3D Version 4.x, allows users to model the coupled behavior of the reactor core and coolant system for various conditions and possible accidents. In FY 2012, the number of active RELAP5-3D licenses increased to 64 active licenses that include more than two dozen foreign entities.

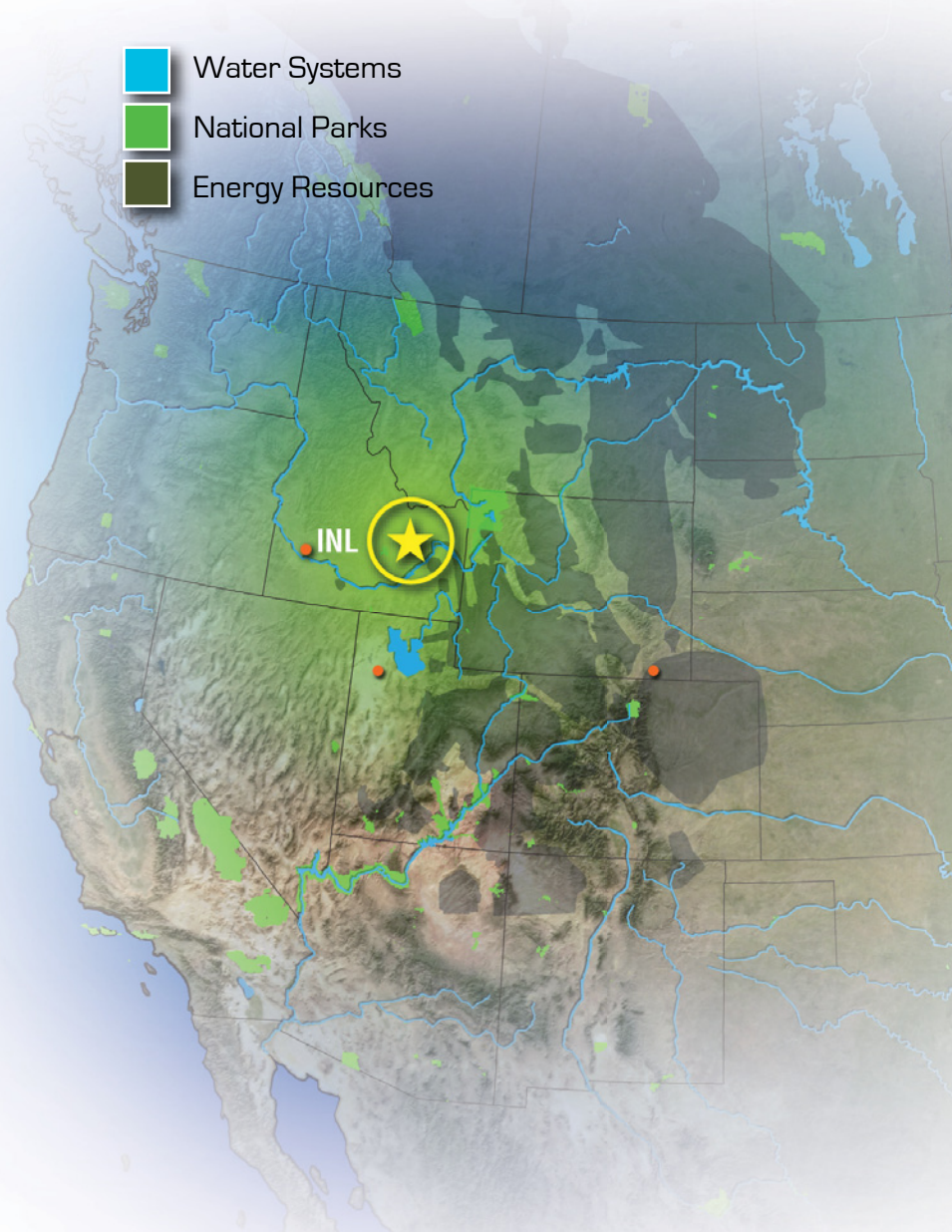
Testing fuels and materials
The nuclear fission process and high radiation fields inside a reactor affect the performance of nuclear fuels and reactor materials. Companies can contract for access to INL material irradiation capabilities at the Advanced Test Reactor and post irradiation examination (PIE) and other capabilities at Materials & Fuels Complex to help test and evaluate these effects. Examples include nuclear fuel work with Westinghouse Electric Company and TerraPower, LLC, and component material testing with Curtiss-Wright Corporation.

Sustaining the fleet
U.S. energy security requires the nation's nuclear reactor fleet — 104 reactors supplying nearly 20 percent of U.S. electricity — to continue safe operation long into the future. INL has a critical role in the DOE's Light Water Reactor Sustainability Program, which works with the nuclear energy industry on technology R&D needs of common interest such as studying material properties for light water reactor life extension. The program's partners include the nonprofit Electric Power Research Institute and more than 30 private companies.

Collaborations WITH...

Domestic and foreign governments

State, regional, national and international policymakers rely upon objective data to inform their decisions. So do government agencies and associations. INL serves as an honest broker of objective research and analysis, which is why such entities often partner with the lab to access its expertise and research solutions to a broad array of challenges.



U.S. defense agencies

The U.S. Department of Defense is working to secure its energy sources and meet renewable energy mandates at military installations. INL is providing project development and engineering support for multiple DOD wind and solar energy projects around the U.S. including:

- Wyoming's F.E. Warren Air Force Base (wind),
- a potential National Guard project in Cheyenne, Wyo. (wind),
- Utah's Test and Training Range-South (geothermal) and
- Idaho's Mountain Home Air Force Base (geothermal).

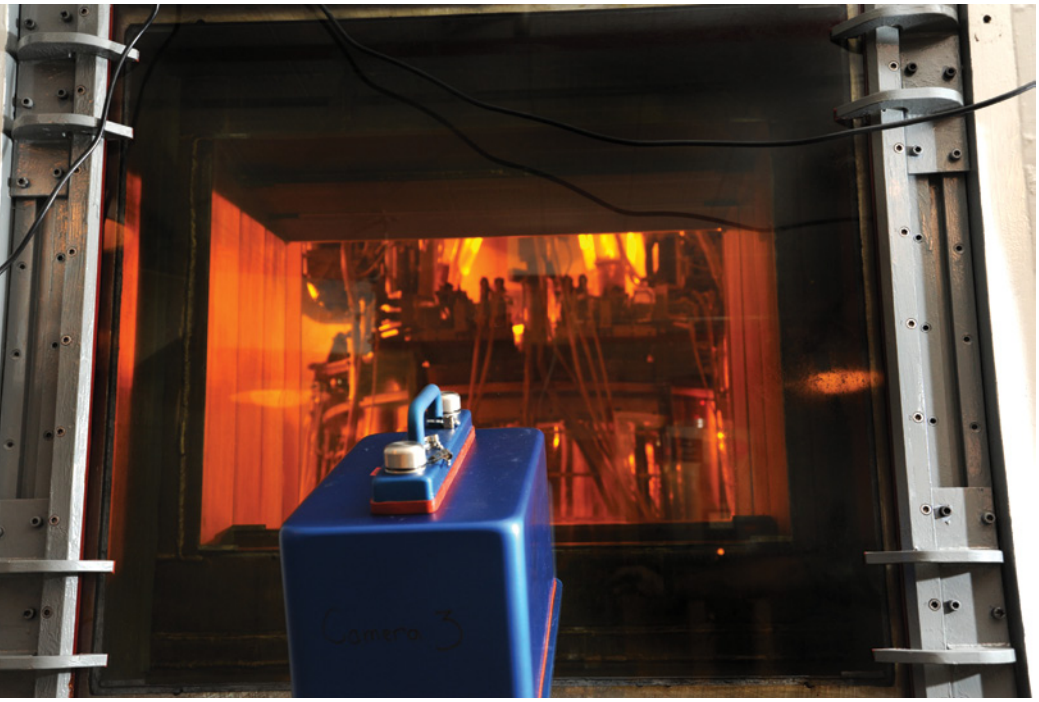
INL cybersecurity experts also worked with the Defense Department to assess the physical and cybersecurity of critical infrastructure at two U.S. Naval bases and provide recommendations for enhancing the protection of critical resources and interconnected systems. INL's expertise led to the creation of a modeling and simulation tool that enables military installations or other government facilities to roughly assess their vulnerabilities using existing data sources. These are just a few of the dozens of Defense Department collaborations at INL.

Military research
The DOD is exploring options for nuclear energy systems to generate electricity for in-theater military operations. INL identified the required capabilities and evaluated the time scales to design, build and test a prototype small modular reactor for the Defense Advanced Research Projects Agency (DARPA). The insight gained about operational constraints led DARPA to request a second phase of research focusing on more pioneering concepts. INL is working with experts inside and outside the lab to narrow the options and identify capability gaps.

International Atomic Energy Agency
Increased worldwide interest in a nuclear recycling technique called pyroprocessing necessitates the expansion of IAEA inspector skills. INL responded by offering specialized training for IAEA inspectors and analysts to familiarize them with the fundamentals, equipment and proliferation concerns associated with pyroprocessing. The lab has recruited top nonproliferation experts with real-world experience, and it has experience designing, developing and operating pyroprocessing facilities.

Mongolian government
INL experts were among seven U.S. participants at the second U.S.-Mongolia Expert Level meeting in August 2012. INL's Steve Herring and Bonnie Hong joined representatives from the DOE, the NRC, the U.S. State Department and Texas A&M University. Meeting participants discussed key initiatives necessary for safely and securely deploying a nuclear energy program in emerging countries.

Estonian government
The Estonian government, in its efforts to help secure its national energy infrastructure, visited INL to gather information on methods and procedures for critical infrastructure cyber assessments. The director general of the Estonian Information Systems Authority and a five-person delegation visited INL to discuss critical infrastructure protection. The meeting request followed an INL-invited presentation on the topic at the European Union Conference on Raising Public Awareness about the Information Society in Tallinn, Estonia.



Designs for small modular reactors, above, are being evaluated for DARPA. INL's Fuel Conditioning Facility, left, offers an ideal location to help IAEA inspectors train to detect pyroprocessing activity in member nations.

Collaborations WITH...

Academia and others

National labs exist partially to conduct research and development that isn't right for industry or academia. But close partnerships with these and other entities help ensure transition of research into nationally significant results. Such collaborations grow every year, and in FY 2012, INL realized a 10 percent increase in university collaborations as graduate students were authorized to complete research at INL facilities.

In FY 2012, a record 1,500 students applied for internships at INL. About 200 students, including 36 graduate students and 20 doctoral candidates, interned at the lab last year. For the fourth consecutive year, INL was among institutions recognized in the independent Vault Guide to top internships.

Idaho Falls Power

INL is working with its local electric company on numerous energy research projects. For one, Idaho Falls Power has participated in beta-testing and demonstration of INL cybersecurity technologies and software that can help utilities protect their control systems. INL researchers also helped develop and evaluate the network Idaho Falls Power devised to accommodate its participation in the Pacific Northwest Smart Grid Demonstration Project. Finally, a collaboration between researchers with the Center for Advanced Energy Studies at INL, the Idaho Falls School District and Idaho Falls Power is collecting and analyzing data from three wind projects and three solar projects, all of which feed into the utility's electric grid.

University researchers

The Advanced Test Reactor (ATR) National Scientific User Facility (NSUF) continued to grow in FY 2012. User facility experiments were performed in four of the partner facilities, and three new partner facilities were added to the program. User facility research, including irradiation and materials property measurement experiments, could help regulators refine safety margins for continued safe operation of the nation's current reactors. New capabilities at Purdue University, Pacific Northwest National Laboratory and Oak Ridge National Laboratory bring to 15 the number of unique capabilities accessible through the user facility.

INL proposed, championed and implemented DOE's Nuclear Energy University Programs to strengthen U.S. nuclear science and engineering education and to coordinate research efforts. In 2012, the program was administering more than $47 million

awarded to 46 colleges and universities. Awards included 39 undergraduate fellowships, 31 fellowships, 26 grants for infrastructure and reactor upgrades, and 48 R&D projects. Since 2009, NEUP has awarded $219 million to 81 schools in 34 states and the District of Columbia.

Grid protection

A first-of-its-kind gathering of DOE policy and technical experts, the U.S. intelligence community and industry discussed how to protect the nation's power and distribution system from emerging threats. INL hosted the Grid Protection workshop, which was sponsored by DOE's Office of Intelligence and Counterintelligence. It provided a forum to discuss threats, information sharing and future technology needs. This interaction typifies the type of collaboration between federal agencies and private industry that can underlie deployment of analytical products and technologies that improve response to national security threats.

Emergency outage recovery

Failed electricity transformers can take up to 18 months to replace. The Department of Homeland Security Recovery Transformer Project met a national demonstration objective to test emergency response to major outages of transmission-level transformers. INL acted as a technical consultant for DHS and EPRI, which led the effort to transport an emergency response recovery transformer from the ABB factory in St. Louis and install it at CenterPoint Energy in Houston.

Participants in the 2012 ATR NSUF Users Week, below.

Worldwide modeling efforts

The MOOSE simulation framework has revolutionized predictive modeling work in an array of scientific fields. MOOSE and MOOSE-based applications are currently licensed for use by 25 domestic and foreign laboratories, universities, and companies; and the user community is growing rapidly.

Active MOOSE license agreements:

- Pacific Northwest National Laboratory
- Los Alamos National Laboratory
- Bechtel Marine Propulsion Corporation
- ANATECH
- Studsvik Scandpower
- University of Chicago Argonne
- Sandia National Laboratories
- Massachusetts Institute of Technology
- University of Wisconsin-Madison
- University of Tennessee
- Mississippi State University
- UT Battelle, LLC – CASL
- Atomic Energy of Canada, Ltd.
- The Pennsylvania State University
- Colorado State University
- General Atomics
- BYU-Idaho
- National Nuclear Laboratory Ltd.
- Royal Military College of Canada
- Institute of Earth Science and Engineering
- Oregon State University

NEW Capabilities

Strategic Infrastructure

Several projects completed in FY 2012 add to an irreplaceable array of capabilities that work toward achieving the strategic infrastructure outlined in INL's Ten-Year Site Plan. The full complement of capabilities enables INL to respond to today's nuclear energy challenges, serve as a multiprogram laboratory with broad competencies in the energy and security sectors, and address the challenges ahead.

The Research and Education Laboratory will serve as the gateway to the Adanced Test Reactor National Scientific User Facility.

Research and Education Laboratory
Construction started last year on the 148,000-square-foot Research and Education Laboratory, above left, which will co-locate DOE program space with user facilities and serve as the gateway to the Advanced Test Reactor National Scientific User Facility based at INL. A public, multiuse auditorium with a 300-seat space will enable increased access by visiting scientists and the public to INL events, symposia and conferences of greater size and scope than current INL facilities allow.

Energy Systems Laboratory
INL researchers are currently moving into the new 91,000-square-foot Energy Systems Laboratory (ESL), above right. This state-of-the-art research facility will support key DOE advanced energy programs and projects. The facility will enable expansion of INL's grid-interface/energy storage capability, an important area for all future electrical generation options. The ESL provides a national capability to help DOE address strategic bioenergy and energy storage objectives.

Threat assessment center
By standing up the Industrial Control System Mission Support Center, INL demonstrated the impact of establishing a national threat analysis and response capability. The center provides the ability to assess and evaluate a spectrum of threats and risks to the nation's critical infrastructure. It has earned visits from DOE's energy secretary, deputy energy secretary, assistant secretary for electricity delivery and energy reliability, and director of intelligence and counterintelligence.

INL completed construction of the Irradiated Materials Characterization Laboratory, a versatile Hazard Category 2 nuclear facility designed for prototyping, developing, and testing advanced post-irradiation examination instruments and methods.

Human Systems Simulation Laboratory
A full complement of digital panels representing a complete nuclear plant control room, above, is enabling research and experimentation that cannot be done elsewhere. The new Human Systems Simulation Laboratory — funded by DOE's Light Water Reactor Sustainability Program — includes 15 virtual control room panels that are supporting the modernization of legacy information, instrumentation and control systems. The lab also provides an operating model to significantly enhance nuclear safety, worker productivity and overall plant performance (more human systems simulation on pg. 14).

NEW Capabilities

Wireless testing capabilities
Growing wireless communication usage and finite available spectrum bandwidth will continue to limit data transmission quantity and speeds. Idaho's isolated landscape provides an unmatched location for full-scale open-air experimentation by those wanting to test options for increasing network efficiency, improving security, and making more effective use of available bandwidth. INL's experienced communications engineers, below, help test and evaluate wireless devices and hardware that span high-frequency, ultra-high-frequency, cellular, satellite, and microwave.

In FY 2012, INL enhanced its Wireless Test Bed by adding 4G capability (Mobile WiMAX) and completed initial cyber assessments and spectrum interference tests of various 4G systems. The test bed accommodated roughly 250 test days for 11 separate customers last year. It also hosted more than 30 meetings with representatives from regulatory bodies, government agencies, academia and industry, including most major cellular providers and carriers eager to partner with INL to enhance the nation's capabilities.

Battery testing
Expanding light duty electric vehicle use is a sustainable energy priority, and battery-based energy storage will help deploy hybrid and renewable energy systems. INL significantly expanded its electric vehicle and stationary battery testing capability with more than $5 million worth of new equipment. A new shaker system subjects prototype and production-ready automotive energy storage devices, particularly Lithium-ion battery packs, to vibration testing. Such treatment evaluates susceptibility to thermal runaway under normal or extreme conditions and helps improve the overall design robustness. Battery testing enhancements significantly expanded to include large walk-in environmental temperature chambers that accommodate several full-size vehicle battery systems, in addition to several dozen smaller chambers for testing small cells and devices.

INL's Dynamic Energy Storage Laboratory provides a test bed to demonstrate several key principles.

INL's expanded vehicle and battery testing facility, below, and its Dynamic Energy Storage Lab, left.

Dynamic Energy Storage Lab

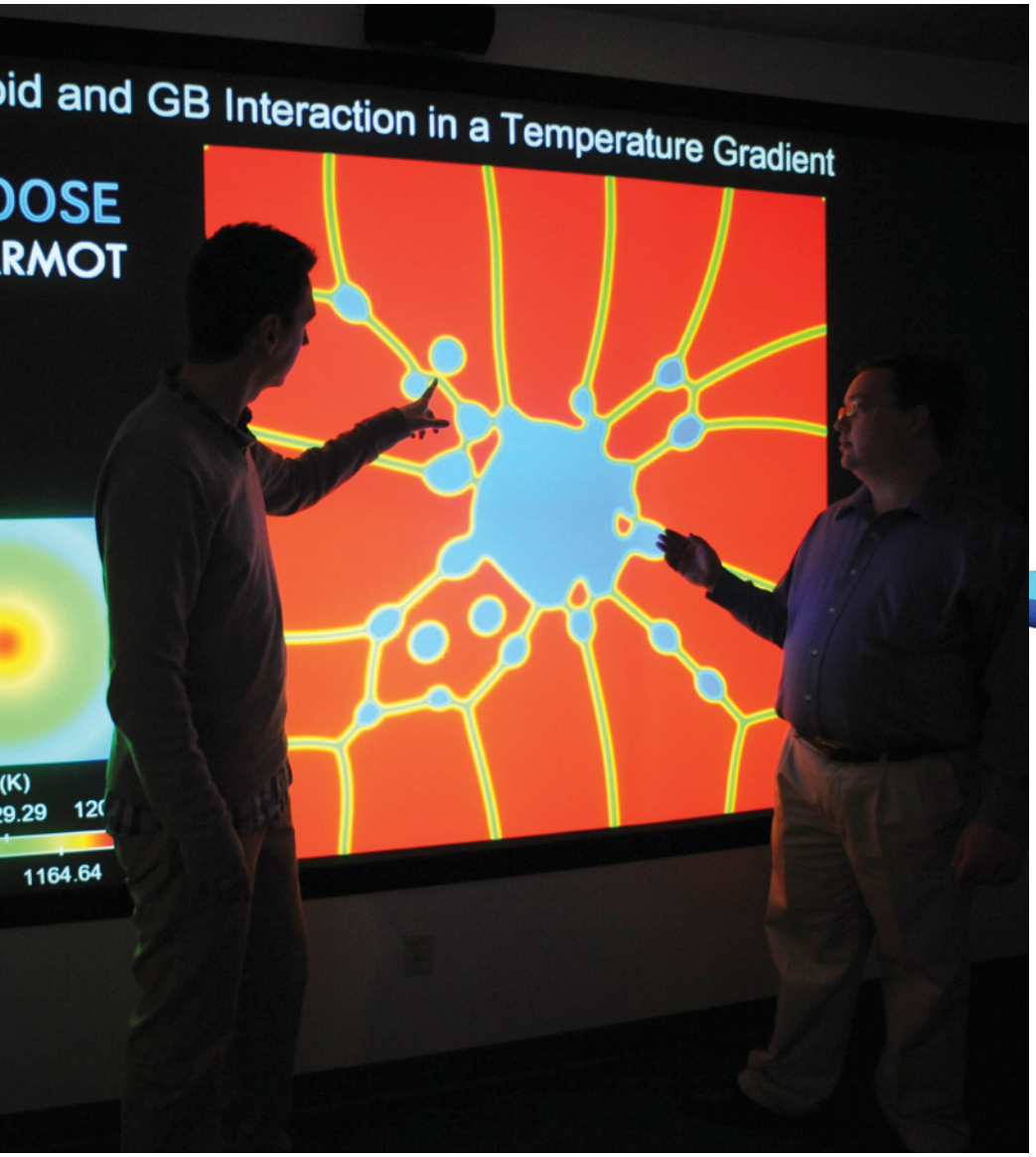
The DOE, Department of Defense, and industry have recognized that small modular conversion plants could better exploit remote and stranded energy assets such as natural gas that is co-produced with oil in remote environmentally sensitive locations. INL's Dynamic Energy Storage Laboratory (DESL) provides a test bed to demonstrate several key principles including:

- remote conversion of electricity and carbon-based resources into synthetic fuels (synfuels),
- technical and economic feasibility of a modular, deployable energy conversion system and
- remote monitoring and control using a real-time system.

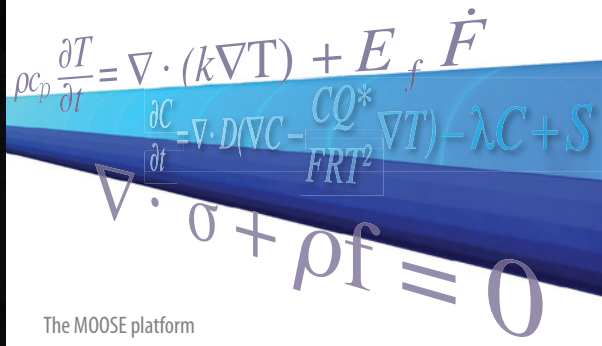
INL completed setup and testing of new equipment associated with DESL, and co-located with the Hydrogen Laboratory. The integrated test bed now includes high pressure hydrogen production, syngas compression and recirculation, synfuel production, and byproduct gas management.

The national nuclear lab

Exceptional expertise, unique infrastructure, nuclear materials and strategic partnerships converge at INL, the nation's nuclear energy laboratory. INL's world-class capabilities and integrated infrastructure support a science-based approach: experimentation, theory, modeling and simulation, and first-of-a-kind demonstration. This approach yields technically achievable, economically competitive and environmentally sustainable options for the entire nuclear enterprise.



Spawning simulation tools
The MOOSE simulation platform developed at INL has inspired creation of a suite of codes used to advance the understanding of nuclear fuel performance. BISON is a thermo-mechanical code exploring fuel performance at the engineering scale. The MARMOT code models fuel changes occurring at the microscale due to radiation damage. MOOSE can couple BISON with MARMOT to improve predictions.



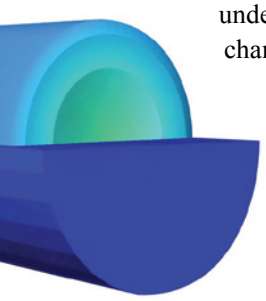
The MOOSE platform generates striking simulations as shown by MARMOT, left, by solving complex mathematical models. For example, the BISON application, above, solves a set of equations describing nuclear fuel pin behavior inside working reactors.

Since this publication first described these tools last year, numerous additions have been added to the "herd." PEREGRINE is an offshoot of BISON designed specifically to model light water reactor fuel performance. It incorporates proprietary Electric Power Research Institute (EPRI) models and supports DOE's Consortium for Advanced Simulation of Light Water Reactors.

Modeling multitudes

Other applications developed under the MOOSE framework include the Grizzly code for materials aging, which is being developed jointly with Oak Ridge National Lab and EPRI. The code models degradation in reactor pressure vessels and other components, which can build up after years of use.

Data from Grizzly could help nuclear power plant owners understand the sources of change in safety margin and inform decisions on component replacement and repair.



The RattleS$_n$ake code could be used to design and study new nuclear fuels with enhanced accident tolerance. The code models the behavior of neutrons in nuclear fuel and reactor cores. A better understanding of this neutron transport physics can sharpen understanding of factors that impact energy generation and material damage.

Simulating safety analytics

INL's premier reactor safety and systems analysis tool will soon be MOOSE-based. The Reactor Excursion and Leak Analysis Program's newest version, RELAP-7, will include several improvements including enhanced models, improved numerical approximations and the ability to couple with multidimensional core simulators being developed in other DOE research programs. The RAVEN software tool will provide a RELAP-7 user interface and use RELAP-7 to perform Risk Informed Safety Characterization.

Broadening approach

Probabilistic risk assessment, fuels with enhanced accident tolerance, and instrumentation improvements all relate to broader questions of light water reactor safety. Yet specialized research programs like this can become isolated. That's why INL is taking a more systems-based approach to reactor safety methodology. A new program at the lab will integrate these areas to enable the advances that result from broader collaborations.

Producing safer waste forms

The DOE and INL are studying advanced nuclear waste forms that may perform better than the global standard. For example, glass waste forms isolate radioactive materials very effectively but their effectiveness is limited by the temperatures that can be achieved in conventional melters. INL has developed a more efficient approach for making advanced glass-ceramic waste forms, right, and successfully demonstrated that approach last year. The lab's state-of-the-art Cold Crucible Induction Melter has unique features that are well suited for producing advanced glass-ceramic high-level waste forms, such as the ability to operate at higher temperatures than conventional melters.

Recognizing Expertise

Derek Gaston
An INL computational mathematician was one of 96 recipients of the 2012 Presidential Early Career Award for Scientists and Engineers. Derek is INL's first recipient of the award, the highest honor the U.S. government bestows on early career science and engineering professionals. The Computational Frameworks Group lead for INL's Fuels Modeling and and Simulation Department led development of the MOOSE simulation framework (more MOOSE on pp. 4, 19, 24).

Richard Martineau
The director of INL's Fuels Modeling and Simulation Department has been widely sought to highlight the MOOSE simulation platform and its associated applications. In 2012, he travelled to more than a dozen symposia in six states, Washington, D.C., and abroad. Rich also was selected as the technical program chair for the 2013 International Conference on Mathematics and Computation Methods Applied to Nuclear Science and Engineering.

Kathryn McCarthy
The director of DOE's Light Water Reactor Sustainability Program Technical Integration Office at INL was asked to serve on a National Academy of Sciences committee to assess the prospects for inertial confinement fusion energy systems. Kathy also received a Nuclear Energy Advocate of the Year Award from Idaho's Partnership for Science & Technology.

Steven Hayes
This INL nuclear engineer directing irradiation testing and post-irradiation examination at INL was selected to lead a program for the DOE's Office of Nuclear Energy. Steve is now the Fuel Modeling & Simulation technical lead for the office's Nuclear Energy Advanced Modeling and Simulation program.

Chang Oh
A distinguished INL engineer was named the 2012 recipient of the American Society of Mechanical Engineers (ASME) Heat Transfer Memorial Award in the art of heat transfer category. In 2011, Chang earned the INL Laboratory Director's Award for Exceptional Engineering Achievement.


Richard Martineau

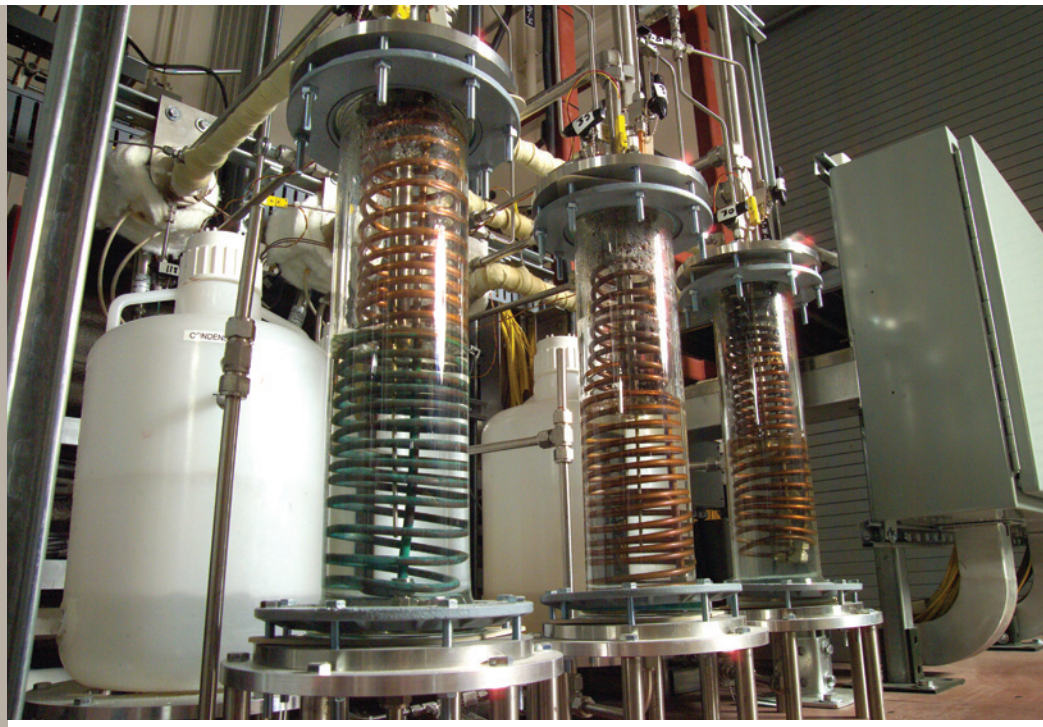

Kathryn McCarthy

Secretary Chu Awards
Achievement Awards from Energy Secretary Steven Chu went to 20 INL employees. The Secretary's Honor Awards program recognizes outstanding efforts in supporting DOE programs. A team of 16 INL employees was honored for efforts supporting the successful Mars Science Laboratory Multi-Mission Radioisotope Thermoelectric Generator project. They were: **Jeremy Andersen, Christian Browning, Carla Dwight, Eric Clarke, Greg Hula, Stephen G. Johnson, SueAnn Keller, Kristoffer Kelly, Kelly Lively, Jamie Mitchell, Gregg Moedl, Chauncey Peters, Amy Powell, Robin Stewart, Courtney Swassing,** and **Darrell Wheeler.**

INL's **Igor Bolshinsky** and **Eric Woolstenhulme** were honored for supporting the Seoul Nuclear Security Summit, the largest summit ever held in the nuclear security field. INL employees **Thomas Johnson** and **Michael N. Patterson** were honored for efforts with the Argonne National Laboratory Footprint Reduction Program.


Steven Hayes


Chang Oh



Producing hydrogen
Processes like petroleum refining require hydrogen, which is typically produced by splitting natural gas. INL has demonstrated an efficient way to make hydrogen and synthetic gas from high-temperature steam. The decade-long project yielded numerous awards and grew the program to international status. The team produced six book chapters, 29 journal articles, 104 conference publications, 37 DOE milestone reports, and three U.S. patents. Most significantly, overall efficiency of the process improved from 28 percent to 50 percent over the course of the project.

INL's high-temperature electrolysis capability encompasses steam electrolysis for hydrogen production, co-electrolysis for direct production of syngas and reversible solid oxide cells for alternating hydrogen production and power production in energy storage strategies.

ADVANCING Technology: INFRASTRUCTURE SECURITY

Protecting critical infrastructure

America's economic, energy and national security depends upon infrastructure that includes wireless communication systems, electric power grids and industrial control systems. For nearly a decade, INL has been internationally recognized for research capabilities that squarely intersect each of these areas and enable the nation to address current and emerging challenges.

Securing industrial control systems

The nation's critical energy infrastructure ranges from systems that light cities to networks that deliver oil and gas. Supervisory control and data acquisition (SCADA) systems monitor and manage this complex, interdependent infrastructure. The DOE's National SCADA Test Bed program recommends protection strategies that help private utilities improve the resilience of such control systems. Five national labs and more than a dozen industry partners contribute to the program, with leadership support from INL.

The lab's full-scale, industry-provided SCADA systems enable routine cyber-analysis by experts. INL also conducts onsite assessments and training — vendors representing more than 85 percent of the energy market have participated. This vast experience provided insight that has led to development of cybersecurity tools such as the Sophia software, which makes it easier for industry to secure its control systems (more cybersecurity on pg. 10).

Expanding wireless communications

INL has demonstrated leadership in U.S. government initiatives for wireless spectrum sharing innovation. The lab has earned national recognition for its innovative wireless communications solutions (more on pg. 11) and has received external validation for its ability to serve as a national wireless test bed for spectrum sharing technology testing and evaluation.

One INL expert was invited to testify for a U.S. Congress House committee about the need for national spectrum sharing testing (more on page 31). INL also has participated as a member of

"INL has excellent infrastructure, research teams and facilities ... that can be of great help to support wireless research and experimentation in the nation."

–Wireless industry representatives visiting INL

the White House Office of Science and Technology Policy's Wireless Spectrum Sharing R&D Task Force. The lab is represented on strategic national panels and committees, and its collaborations have advanced partnerships among government, industry, academia and laboratories.

INL hosted a first-of-its-kind government/industry workshop to support spectrum-sharing initiatives. The Spectrum Sharing Technical Workshop helped establish a technical action plan to facilitate spectrum-sharing research experimentation and performance validation. Telecommunication stakeholders included carriers, equipment and device manufacturers, the U.S. Department of Defense, the National Telecommunications and Information Administration, and the Federal Communications Commission spectrum sharing group.

ADVANCING Technology: INFRASTRUCTURE SECURITY

Enhancing cybersecurity

INL provide critical support to the Department of Homeland Security Control System Security Program's Industrial Control System-Cyber Emergency Response Team. This role is the foundation of a public-private partnership between DHS and industry, which aims to develop and deploy innovative tools, training and capabilities that help national and international asset owners during incident handling and response. During FY 2012, ICS CERT provided cybersecurity training to more than 2,300 professionals and conducted more than 85 onsite assessments across infrastructure sectors that include nuclear, oil and gas, and defense industries.

Recognizing expertise

Rita Wells
U.S. Department of Homeland Security Secretary Janet Napolitano appointed INL cyber and control systems security researcher Rita Wells to a 15-member cyberskills task force. The group is developing recommendations to help the federal government recruit and retain talented cybersecurity professionals. Rita is a 22-year INL employee, the lab's electric sector security programs lead, and the recipient of numerous cybersecurity awards including the SANS Institute's SCADA security leadership award. She is a regular invited speaker at national cybersecurity conferences and has provided testimony to Congress outlining cybersecurity challenges in the electric utility sector.

Karl Black
The successful collaboration in developing a Risk Management Methodology and the Dynamic Attack Tree Tool (DATT) earned Karl an award at the 2012 DOE Information Management Conference. This tool can be used to assess risk, especially cyberrisk, by enabling interactive visualization and prioritized documentation of approaches an attacker might take to damage, compromise or steal sensitive information from computers or other electronic devices.

Rangam Subramanian
The U.S. House Science, Space and Technology Committee invited INL's chief wireless and technology strategist to testify at a hearing of the Subcommittee on Technology and Innovation. The hearing focused on "Avoiding the Spectrum Crunch: Growing the Wireless Economy through Innovation." Rangam joined witnesses representing industry and the National Institute of Standards and Technology to support establishing a full-scale national wireless test bed.

"INL, with its strong capabilities in wireless R&D and its full-scale wireless test bed, stands ready to support this national initiative on spectrum-sharing."

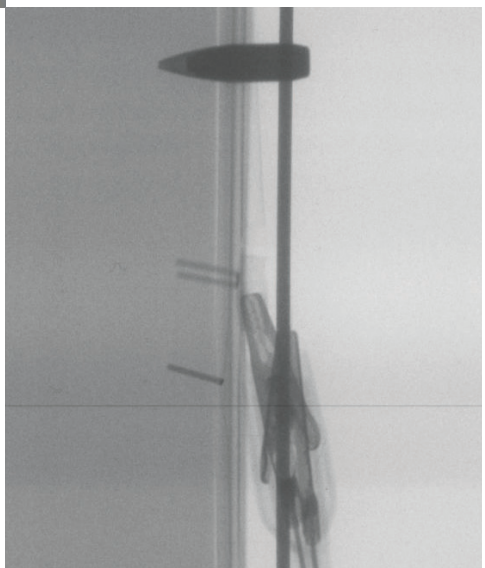
—INL's Rangam Subramanian, U.S. House Science, Space and Technology Committee hearing

Safeguarding soldiers and materials

INL's explosives test range and Radiological Response Training Range enable unmatched testing and training opportunities that benefit the nation's soldiers and first-responders. Building upon its core expertise in nuclear fuel and civilian nuclear energy technologies, INL has become an international resource for securing nuclear material.

Scrutinizing nuclear fuel casks
An INL invention helping the IAEA develop the capability to verify the contents of nuclear fuel dry casks is being demonstrated in Belgium. The Compton Dry-Cask Imaging Scanner, above, enables inspectors to discern the contents of a nuclear fuel storage cask without having to open it. The device sits atop a closed cask, scans each of its storage slots, and uses gamma rays to reveal the presence or absence of fuel rods at each position. The device allows inspectors to independently verify storage records without having to open the casks. It also can help when records aren't available or reliable.

Visualizing bullet impacts
INL enhanced its National Security Test Range by installing a flash X-ray system. This new capability allows stop-motion imaging of bullets penetrating targets, below, and other dynamic events that can't be imaged using conventional high-speed video techniques. The capability will improve researchers' understanding of dynamic ballistic and explosive events, enabling better numerical modeling and improved armor designs.



"This was a very complex operation and it could not have been done without the critical support of your organization."

—Thomas P. D'Agostino, former under secretary for Nuclear Security & Administrator, National Nuclear Security Administration, on the conversion of a Mexican research reactor

Detecting radiation
The CellRAD prototype is an early warning system for detecting radiological materials. Unmodified commercial cellular smartphones can be made to detect nuclear material from several feet away depending upon factors such as source strength, distance from the smartphone and shielding. A large-scale, deployable, mobile network sensor array for radiation detection can be quickly built using software uploaded to an Android smartphone. A host computer can collect the smartphone data to analyze, process and visualize the location of radiation sources. Response personnel may then be notified to investigate or verify initial findings using high-caliber radiological detection equipment.

Radiological response training
First-responders to radiological emergencies are better prepared thanks to training organized by DOE's National Nuclear Security Administration. INL experts are members of International Radiological Assistance Program Training for Emergency Response (I-RAPTER) teams that conducted 2012 training in Thailand, Slovenia and Austria. Collectively, the sessions trained 92 responders representing more than two dozen countries.

Recognizing expertise

Igor Bolshinsky, Mike Tyacke, Ken Allen
INL experts have led operational efforts for the NNSA's Global Threat Reduction Initiative and its continued securing of more than 1,700 kg of Russian-origin highly enriched uranium nuclear fuel. They've helped oversee fuel shipments from Uzbekistan, Poland, Czech Republic and Kazakhstan.

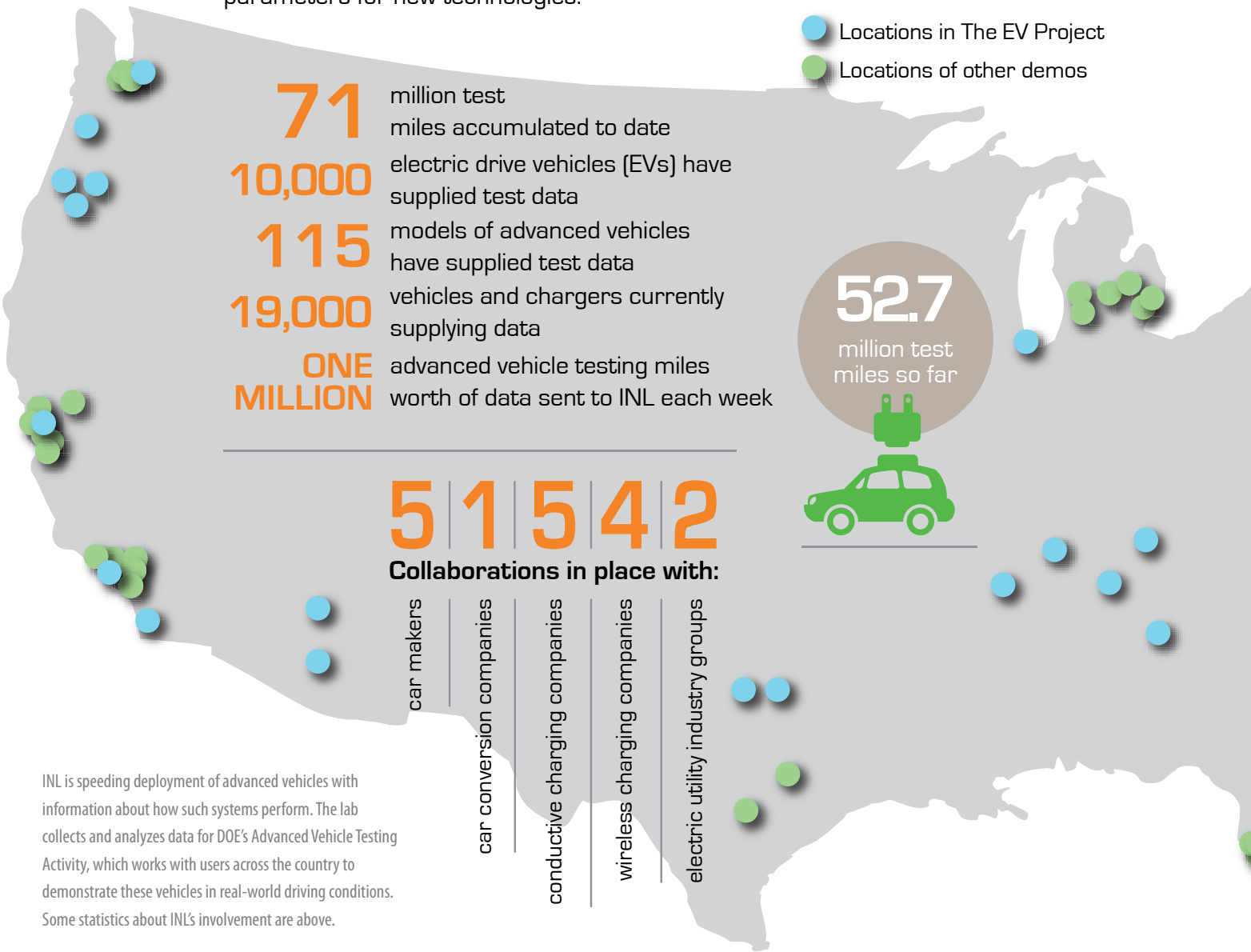
Eric Woolstenhulme
The INL reactor engineer helped convert a research reactor in Mexico to operate using low-enriched uranium. Eric helped orchestrate delivery of the new fuel. President Obama lauded the reactor conversion at the Nuclear Security Summit in South Korea.

Gus Caffrey
INL's Lifetime Achievement Award acknowledges the career achievements of a scientist or engineer who has made nationally and internationally recognized contributions. Gus, holding award at left, has worked as an INL physicist for more than 30 years. He developed the R&D 100 Award-winning Portable Isotopic Neutron Spectroscopy system and the nuclear fuel cask scanner described on the previous page.

ADVANCING Technology: ENERGY SECURITY

Sustainable energy challenge

INL is helping the energy industry and its regulators expand energy supply, improve efficiency and address environmental concerns. The lab partners with universities and industry to help understand and reduce risks associated with deploying new technology. INL's systems engineering expertise drives a big-picture perspective, and distinctive performance testing capabilities help regulators determine the impact and regulatory parameters for new technologies.



INL is speeding deployment of advanced vehicles with information about how such systems perform. The lab collects and analyzes data for DOE's Advanced Vehicle Testing Activity, which works with users across the country to demonstrate these vehicles in real-world driving conditions. Some statistics about INL's involvement are above.

Leading energy advances

INL is providing the thought leadership and research tools that are advancing research, testing and deployment of hybrid energy systems, which pair two or more energy resources to yield energy security benefits. INL partnered with the Joint Institute for Strategic Energy Analysis at the National Renewable Energy Lab to co-sponsor an international hybrid energy systems workshop in Salt Lake City. The workshop identified research topics important for advancing the potential use of hybrid systems, with a specific focus on nuclear-renewable hybrid systems. About 40 people representing national laboratories, universities and energy companies attended from across the U.S., China and France.

Closer to home, INL is encouraging state participation in energy systems planning and assessment, which is important to establishing policy and strategies that enable future energy systems to be built. For example, in FY 2012, the state of Wyoming passed legislation to team with INL. It studied how hybrid energy systems can best be used to convert Wyoming's fossil and wind energy resources into higher value products. The partnership has already delivered its research report to the legislature.

Enhancing biofuel quality

INL is pioneering approaches for processing biomass feedstock for biofuels production, while also developing a commodity concept that could transform biomass utilization. In FY 2012, INL's Bioenergy Program completed 60 milestones set by DOE's Energy Efficiency and Renewable Energy Office of Biomass. These included five top-priority "Joule" milestones.

For example, INL successfully achieved, with third-party validation, feedstock cost targets for corn stover harvest and storage — a key step in making U.S. bioenergy economically sustainable. The lab also leads efforts to formulate unique blends of feedstocks and additives, left, that can improve biofuel production efficiency.

55 experimental runs in the feedstock Process Demonstration Unit at INL

76 tons of biomass processed for 11 project customers

24 technical papers submitted or published by INL biomass researchers

19 conferences where INL biomass researchers presented R&D results, including a keynote address at the Northeast Biomass Heating Symposium

Piloting energy systems
INL has teamed with Western Hydrogen Ltd. to develop a molten salt gasifier that can manufacture hydrogen using organic waste byproducts, such as the heavy residuals produced by oil sands production. INL has built a lab-scale demonstration of its patented technology, and Western Hydrogen has obtained a 50 percent funding match to support design, construction and testing of a pilot plant in Alberta.

Assessing geothermal resources
Siting enhanced geothermal systems requires detailed understanding of subsurface processes, primarily rock permeability. To advance this work, INL capitalizes on its expertise in both subsurface geology and advanced modeling and simulation. The FALCON computer modeling code enables researchers to simulate the physics of these processes with fine resolution while also modeling an entire geothermal reservoir. FALCON was built on INL's MOOSE simulation platform, and is currently licensed to research entities in the U.S., Australia and New Zealand (more modeling on pp. 4, 24).

INL and the University of Utah completed a report assessing geothermal resource potential within Utah's Test and Training Range-South. The report was accepted by Utah's Hill Air Force Base and transmitted to the U.S. Air Force Energy Program Management Office for funding consideration. INL also supported the drilling of an exploratory geothermal slim hole well at Idaho's Mountain Home Air Force Base.

INL experts helped advise student teams participating in the DOE's 2012 National Geothermal Student Competition, which advances geothermal education and generates data that may help industry develop new geothermal sites. This year's competition focused on the potential of Idaho's Snake River Plain.

Recognizing expertise

Erin Searcy
The bioenergy technical and analytical expert in INL's Biofuels and Renewable Energy Technologies Department is on a special one-year assignment at DOE's Office of Biomass Program. Erin is supporting the office's Feedstock Platform by helping establish technical targets and progress metrics, developing and executing key program workshops, and assisting with technical inquiries, working groups and round tables.

Robert Podgorney
The INL manager of Energy Resource Recovery and Sustainability has been appointed to chair a U.S. reservoir modeling working group for the International Partnership for Geothermal Technology. The U.S., Switzerland, Australia, New Zealand and Iceland are collaborating on the planning effort, which will help avoid duplication of research efforts.

Steven Aumeier
INL's associate laboratory director for Energy and Environment Science and Technology, and Center for Advanced Energy Studies director, was a plenary speaker at the International Congress on Advanced Power Plants, where he discussed nuclear hybrid energy systems. Steve also chairs the Idaho Strategic Energy Alliance, which is developing energy plans and strategies for the state's energy future.

Richard Wright, Carl Stoots
The 2012 INL Honors Reception recognized Richard, right, for exceptional scientific achievements related to advanced nuclear reactor materials. Carl, left, was honored for exceptional engineering achievements on high-temperature electrolysis.

UNIVERSITY Collaborative MODEL

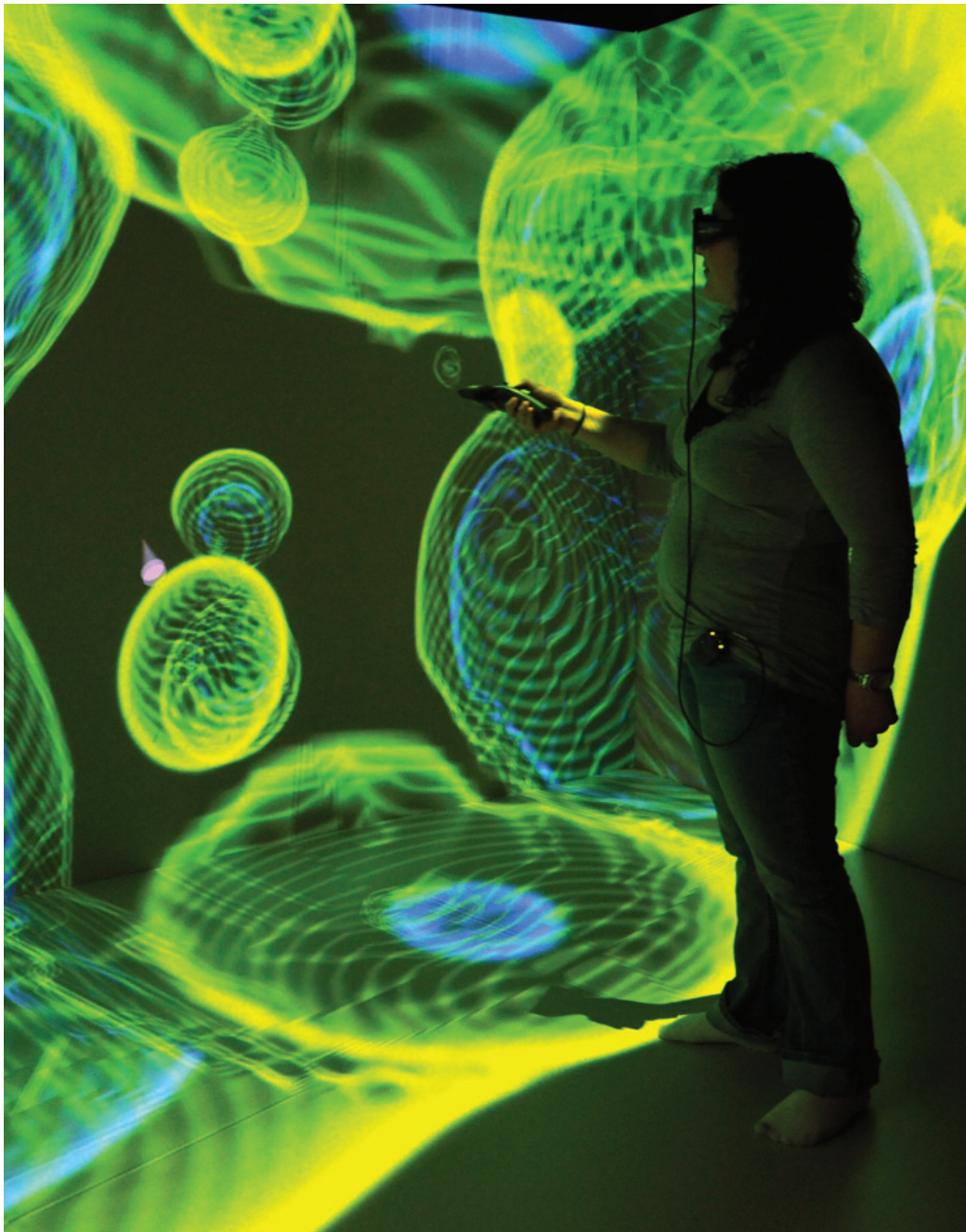
Center for Advanced Energy Studies

This collaboration between INL and Idaho's three public research universities has changed the perception of relationships between the federal government and state entities. CAES is now held up as a model across the DOE complex of how a federal-state partnership can leverage each member's investments to benefit higher education research throughout the state.

Leveraging investments

The CAES partners have proven that a national laboratory and competing public universities can collaborate to achieve results. Researchers from partner institutions work side-by-side to assemble strong, innovative proposals that win funding from a variety of agencies and industries. The CAES model enables the pooling of resources and sharing of equipment, which lets CAES researchers compete with much larger universities to win research dollars.

In addition, the university partners continue to build strong academic programs that are educating a new generation of scientists and engineers. Boise State University recently introduced a doctoral program in materials science and engineering. University of Idaho and Idaho State University continue to build enrollment in nuclear-related fields. And research opportunities at CAES are partly responsible for increasing INL's graduate student internships.



THREE THOUSAND

Number of people who toured CAES and its Computer-Assisted Virtual Environment (CAVE), above, during FY 2012.

Attracting outside users
The CAES Microscopy and Characterization Suite (MaCS) built a strong customer base in FY 2012, attracting users from inside and outside the partnership including: Micron; Nanosteel; University of California, Santa Barbara; University of California, Berkeley; General Electric; Oxford University; University of Florida; Texas A&M; and University of Wisconsin-Madison.

Improving energy efficiency
The CAES Energy Efficiency Research Institute launched a statewide industrial assessment center using a DOE grant. Student teams conducted free energy efficiency assessments for regional companies and manufacturing plants. During FY 2012, the teams conducted eight visits and submitted four reports identifing a total projected energy savings of 1,003,464 kilowatt hours and a potential cost savings of $109,534.

Siting solar energy facilities
The CAES Energy Policy Institute leads a team of 12 researchers that is developing a computer-based Geographic Information System tool to identify potential sites for large-scale solar energy facilities. The tool analyzes natural resources, physical characteristics and public acceptance/opinion of where such farms should be located. The $2.8 million project is being funded through DOE's Sunshot Initiative.

Sponsored by the CAES Energy Policy Institute, the second annual Western Energy Policy Research Conference featured more than 45 presentations from 33 universities, national laboratories and stakeholder groups throughout the U.S., Canada and the United Kingdom.

UNIVERSITY Collaborative MODEL

CAES and its partner institutions support several STEM events throughout the year, including hands-on activities for K-12 students.

Supporting STEM education
More than 400 educators attended four hands-on workshops sponsored by the Idaho Science, Technology, Engineering and Mathematics initiative – or i-STEM – of which CAES is a member. CAES also provided tours to several student groups during FY 2012, including Idaho Science and Aerospace Scholars and My Amazing Future, a female-oriented, hands-on STEM workshop.

FOUR HUNDRED

Number of educators who attended for hands-on workshops sponsored by the Idaho Science, Technology, Engineering and Mathematics initiative.

45 Number of presentations given by universities, national laboratories and stakeholder groups at the second annual Western Energy Policy Research Conference, sponsored by the CAES Energy Policy Institute.

Total amount of competitive research and other funding CAES researchers have won since FY 2008. **50.97 $ MILLION**

The state's return on its FY 2012 investment in the CAES partnership. **5.6:1**

Number of jobs CAES generated in FY 2012 according to a UI assessment. **186**

Number of jobs CAES has generated from FY 2009–2012. **1,075**

Number of students enrolled in nuclear-related degree and certificate programs at the CAES partner universities. **583**

Number of publications, presentations and proceedings CAES researchers produced in FY 2012. **225**

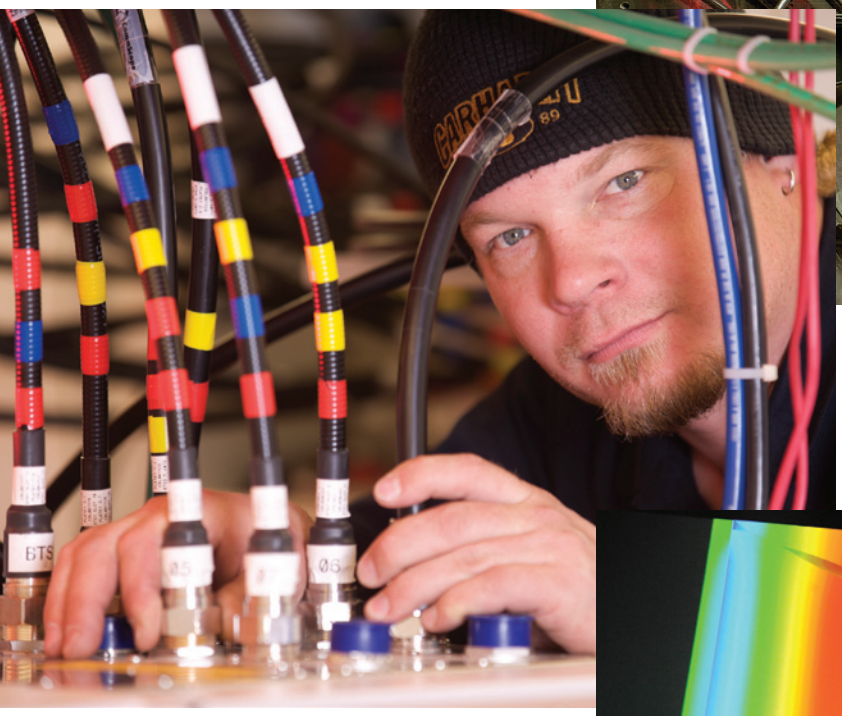
80 People from industry, academia and government agencies converged in Boise to take part in the second annual Idaho Research Symposium, which connects Idaho companies with researchers to spark potential collaborations. In FY 2012, 12 entities sponsored the event, and 58 companies participated.

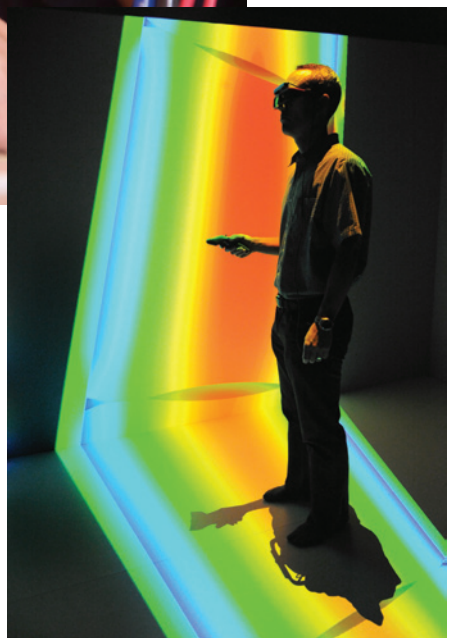
Making the most of manure

A CAES bioenergy research team is investigating using effluent — a liquid waste produced during the anaerobic digestion of dairy manure — to grow algae, which can then be used to make several value-added products. The project — funded by a grant from the U.S. Department of Agriculture — is a collaboration between CAES and the Innovation Center for U.S. Dairy, an industry group committed to reducing greenhouse gas emissions by 20 percent at the nation's dairy farms.

ABOUT INL

In operation since 1949, INL is a science-based, applied engineering national laboratory dedicated to supporting the U.S. Department of Energy's missions in nuclear and energy research, science, and national security.





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